

AMENDMENTS TO THE CLAIMS

Please amend Claims 22, 23, 25, 26, 27, 29, 31, 33, 35, 36, 38, 40, 41, 42, 44, 49, 51, 53, 58, 59, 60, 62, 67, 69, 71, 76, 90, 93, 100 and 108, and cancel Claims 1-20, 21, 30, 88, 89 and 107. Following entry of the amendments in this Amendment, the pending claims in the present application read as follows:

Claims 1-20 (Cancelled)

Claim 21. (Cancelled).

1 22. (Currently Amended) The method of claim ~~24~~29, wherein the step of using
2 centrifugal pump performance values to produce command signals comprises the steps
3 of:

4 selecting a centrifugal pump performance parameter to control;
5 determining a setpoint for the selected centrifugal pump performance parameter;
6 calculating a control signal using the setpoint value of the selected centrifugal
7 pump performance parameter; and
8 calculating the command signals from the control signal.

1 23. (Currently Amended) ~~The method of claim 22,~~ A method of controlling a centrifugal
2 pump for transferring fluid within a fluid system, the method comprising the steps of:

3 determining a value of speed input to the centrifugal pump;
4 determining a value of pump flow rate;

5 using the value of speed input and the value of pump flow rate to calculate one or
6 more values representing the performance of the centrifugal pump;

7 using the centrifugal pump performance values to produce one or more command
8 signals, including the steps of selecting a centrifugal pump performance parameter to
9 control, determining a setpoint for the selected centrifugal pump performance parameter,
10 calculating a control signal using the setpoint value of the selected centrifugal pump
11 performance parameter, and calculating the one or more command signals from the
12 control signal; and

13 using the one or more command signals to control the speed of the centrifugal
14 pump,

15 wherein the selected centrifugal pump performance parameter is the pump flow
16 rate and the step of using the one or more command signals to control the speed of the
17 centrifugal pump includes repetitively switching the speed of the centrifugal pump
18 between a set pump speed for a portion of a cycle period and zero speed for the
19 remainder of the cycle period to achieve an average pump flow rate equal to the setpoint
20 value of the pump flow rate.

1 24. (Original) The method of claim 22, wherein the selected centrifugal pump
2 performance parameter is the pump head pressure.

1 25. (Currently Amended) The method of claim ~~24~~29, wherein the centrifugal pump is
2 coupled to an electric motor and the step of determining the speed input to the centrifugal
3 pump comprises the steps of:

4 measuring values of electrical voltages applied to the motor and currents drawn by
5 the motor; and

6 using the measured values of electrical voltages applied to the motor and currents
7 drawn by the motor to calculate a value for the motor speed.

1 26. (Currently Amended) The method of claim 25, wherein the step of using centrifugal
2 pump performance values to produce the one or more command signals comprises the
3 steps of:

4 selecting a centrifugal pump performance parameter to control;
5 determining a setpoint for the selected centrifugal pump performance parameter;
6 calculating a control signal using the setpoint value of the selected centrifugal
7 pump performance parameter; and
8 calculating the one or more command signals from the control signal.

1 27. (Currently Amended) ~~The method of claim 26,~~ A method of controlling a centrifugal
2 pump for transferring fluid within a fluid system, wherein the centrifugal pump is
3 coupled to an electric motor, the method comprising the steps of:

4 determining a value of speed input to the centrifugal pump, including the steps of
5 measuring values of electrical voltages applied to the motor and currents drawn by the
6 motor, and using the measured values of electrical voltages applied to the motor and
7 currents drawn by the motor to calculate a value for the motor speed;

8 determining a value of pump flow rate;
9 using the value of speed input and the value of pump flow rate to calculate one or
10 more values representing the performance of the centrifugal pump;

11 using the centrifugal pump performance values to produce one or more command
12 signals, including the steps of selecting a centrifugal pump performance parameter to
13 control, determining a setpoint for the selected centrifugal pump performance parameter,
14 calculating a control signal using the setpoint value of the selected centrifugal pump
15 performance parameter, and calculating the one or more command signals from the
16 control signal; and

17 using the one or more command signals to control the speed of the centrifugal
18 pump.

wherein the selected centrifugal pump performance parameter is the pump flow rate and the step of using the one or more command signals to control the speed of the centrifugal pump includes repetitively switching the speed of the centrifugal pump between a set pump speed for a portion of a cycle period and zero speed for the remainder of the cycle period to achieve an average pump flow rate equal to the setpoint value of the pump flow rate.

28. (Original) The method of claim 26, wherein the selected centrifugal pump performance parameter is the pump head pressure.

29. (Currently Amended) ~~The method of claim 21~~ A method of controlling a centrifugal pump for transferring fluid within a fluid system, the method comprising the steps of:

determining a value of speed input to the centrifugal pump;

determining a value of pump flow rate;

using the value of speed input and the value of pump flow rate to calculate one or more values representing the performance of the centrifugal pump;

using the centrifugal pump performance values to produce one or more command signals; and

using the command signals to control the speed of the centrifugal pump,

wherein the values representing the performance of the pump comprise values representing pump mechanical input power limit and pump mechanical input power, and the step of using the one or more command signals to control the speed of the centrifugal pump ~~comprises~~includes the steps of:

comparing the pump mechanical input power limit and pump mechanical input power; and

reducing the speed of the centrifugal pump if the value of pump mechanical input power is greater than the pump mechanical input power limit.

30. (Cancelled).

31. (Currently Amended) The method of claim ~~30~~ 40, wherein the step of using centrifugal pump performance values to produce the one or more command signals comprises the steps of:

- selecting a centrifugal pump performance parameter to control;
- determining a setpoint for the selected centrifugal pump performance parameter;
- calculating a control signal using the setpoint value of the selected centrifugal pump performance parameter; and
- calculating the one or more command signals from the control signal.

32. (Original) The method of claim 31, wherein the selected centrifugal pump performance parameter is the pump flow rate.

33. (Currently Amended) ~~The method of claim 32,~~ A method of controlling a centrifugal pump for transferring fluid within a fluid system, the method comprising the steps of:

- determining a value of speed input to the centrifugal pump;
- determining a value of torque input to the centrifugal pump;
- using the value of speed input and the value of torque input to calculate one or more values representing the performance of the centrifugal pump;
- using the centrifugal pump performance values to produce one or more command signals, including the steps of selecting a centrifugal pump performance parameter to control, determining a setpoint for the selected centrifugal pump performance parameter, calculating a control signal using the setpoint value of the selected centrifugal pump performance parameter; and calculating the one or more command signals from the control signal, and

13 using the one or more command signals to control the speed of the centrifugal
14 pump,
15 wherein the selected centrifugal pump performance parameter is the pump flow
16 rate and wherein the step of using the one or more command signals to control the speed
17 of the centrifugal pump includes repetitively switching the speed of the centrifugal pump
18 between a set pump speed for a portion of a cycle period and zero speed for the
19 remainder of the cycle period to achieve an average pump flow rate equal to the setpoint
20 value of the pump flow rate.

1 34. (Original) The method of claim 31, wherein the selected centrifugal pump
2 performance parameter is the pump head pressure.

1 35. (Currently Amended) The method of claim ~~30~~ 40, wherein the centrifugal pump is
2 coupled to an electric motor and the step of determining the speed input and the torque
3 input to the centrifugal pump comprises the steps of:

4 measuring values of electrical voltages applied to the motor and currents drawn by
5 the motor; and

6 using the measured values of electrical voltages applied to the motor and currents
7 drawn by the motor to calculate a value for at least one of the parameters selected from
8 the group consisting of motor torque and the motor speed.

1 36. (Currently Amended) The method of claim 35, wherein the step of using centrifugal
2 pump performance values to produce the one or more command signals comprises the
3 steps of:

4 selecting a centrifugal pump performance parameter to control;
5 determining a setpoint for the selected centrifugal pump performance parameter;
6 calculating a control signal using the setpoint value of the selected centrifugal
7 pump performance parameter; and

calculating the one or more command signals from the control signal.

37. (Original) The method of claim 36, wherein the selected centrifugal pump performance parameter is the pump flow rate.

38. (Currently Amended) ~~The method of claim 37,~~ A method of controlling a centrifugal pump for transferring fluid within a fluid system, wherein the centrifugal pump is coupled to an electric motor, the method comprising the steps of:

determining a value of speed input to the centrifugal pump and determining a value of torque input to the centrifugal pump, including measuring values of electrical voltages applied to the motor and currents drawn by the motor, and using the measured values of electrical voltages applied to the motor and currents drawn by the motor to calculate a value for at least one of the parameters selected from the group consisting of motor torque and the motor speed;

using the value of speed input and the value of torque input to calculate one or more values representing the performance of the centrifugal pump;

using the centrifugal pump performance values to produce one or more command signals, including the steps of selecting a centrifugal pump performance parameter to control, determining a setpoint for the selected centrifugal pump performance parameter, calculating a control signal using the setpoint value of the selected centrifugal pump performance parameter, and calculating the one or more command signals from the control signal; and

using the one or more command signals to control the speed of the centrifugal pump,

wherein the selected centrifugal pump performance parameter is the pump flow rate; and wherein the step of using the one or more command signals to control the speed of the centrifugal pump includes repetitively switching the speed of the centrifugal pump

23 between a set pump speed for a portion of a cycle period and zero speed for the
24 remainder of the cycle period to achieve an average pump flow rate equal to the setpoint
25 value of the pump flow rate.

1 39. (Original) The method of claim 36, wherein the selected centrifugal pump
2 performance parameter is the pump head pressure.

1 40. (Currently Amended) ~~The method of claim 30~~ A method of controlling a centrifugal
2 pump for transferring fluid within a fluid system, the method comprising the steps of:
3 determining a value of speed input to the centrifugal pump;
4 determining a value of torque input to the centrifugal pump;
5 using the value of speed input and the value of torque input to calculate one or
6 more values representing the performance of the centrifugal pump;
7 using the centrifugal pump performance values to produce one or more command
8 signals; and
9 using the one or more command signals to control the speed of the centrifugal
10 pump,
11 wherein the values representing the performance of the pump comprise values
12 representing pump mechanical input power limit and pump mechanical input power, and
13 the step of using the one or more command signals to control the speed of the centrifugal
14 pump ~~comprises~~ includes the steps of:
15 comparing the pump mechanical input power limit and pump mechanical input
16 power; and
17 reducing the speed of the centrifugal pump if the value of pump mechanical input
18 power is greater than the pump mechanical input power limit.

1 41. (Currently Amended) A method of controlling the performance of a fluid system
2 wherein a centrifugal pump is used for transferring fluid within said fluid system, the
3 method comprising the steps of:
4 determining values of torque and speed inputs to the centrifugal pump;
5 using the values of torque and speed inputs to calculate one or more values
6 representing the performance of the centrifugal pump;
7 using the values representing the performance of the centrifugal pump to calculate
8 values representing the performance of the fluid system;
9 using the system performance values to produce one or more command signals,
10 including deriving a setpoint value for a fluid system performance parameter from a fluid
11 level command, and using the setpoint value in calculating the one or more command
12 signals; and
13 using the one or more command signals to control the speed of the centrifugal
14 pump.

1 42. (Currently Amended) The method of claim 41, wherein the step of using fluid system
2 performance values to produce the one or more command signals comprises the further
3 steps of:
4 selecting a fluid system performance parameter to control;
5 ~~determining a~~ the setpoint value being derived for the selected fluid system
6 performance parameter;
7 calculating a control signal using the setpoint value of the selected fluid system
8 performance parameter; and
9 calculating the one or more command signals from the control signal.

1 43. (Original) The method of claim 42, wherein the selected fluid system performance
2 parameter to control is the pump suction pressure.

1 44. (Currently Amended) ~~The method of claim 43,~~ A method of controlling the
2 performance of a fluid system wherein a centrifugal pump is used for transferring fluid
3 within said fluid system, the method comprising the steps of:
4 determining values of torque and speed inputs to the centrifugal pump;
5 using the values of torque and speed inputs to calculate one or more values
6 representing the performance of the centrifugal pump;
7 using the values representing the performance of the centrifugal pump to calculate
8 values representing the performance of the fluid system;
9 using the system performance values to produce one or more command signals,
10 including the steps of selecting a fluid system performance parameter to control,
11 determining a setpoint for the selected fluid system performance parameter, calculating a
12 control signal using the setpoint value of the selected fluid system performance
13 parameter, and calculating the one or more command signals from the control signal, and
14 using the command signals to control the speed of the centrifugal pump,
15 wherein the selected fluid system performance parameter to control is the pump
16 suction pressure and further comprising the step of deriving the setpoint value for pump
17 suction pressure from a fluid level command.

1 45. (Original) The method of claim 44, further comprising the step of determining the
2 fluid level command, said step of determining the fluid level command comprising the
3 steps of:
4 defining a fluid system performance characteristic to optimize;
5 varying the fluid level incrementally through a range of values;

6 determining a value representing the fluid system performance characteristic for
7 each value of fluid level;

8 determining for which value of fluid level the value representing the fluid system
9 performance characteristic is optimized; and

10 setting the fluid level command at the level which produces the optimized value.

1 46. (Original) The method of claim 45, wherein the step of determining the fluid level
2 command is automatically repeated at predetermined times.

1 47. (Original) The method of claim 45, further comprising the step of periodically
2 determining the pump efficiency and repeating the step of determining the fluid level
3 command when a decrease in pump efficiency relative to prior determinations of pump
4 efficiency is detected.

1 48. (Original) The method of claim 45, wherein the fluid system is a gas well, further
2 comprising the step of periodically determining the gas production and repeating the step
3 of determining the fluid level command when a decrease in gas production relative to
4 prior determinations of gas production is detected.

1 49. (Original/Currently Amended) ~~The method of claim 43,~~ A method of controlling the
2 performance of a fluid system wherein a centrifugal pump is used for transferring fluid
3 within said fluid system, the method comprising the steps of:

4 determining values of torque and speed inputs to the centrifugal pump;
5 using the values of torque and speed inputs to calculate one or more values
6 representing the performance of the centrifugal pump;
7 using the values representing the performance of the centrifugal pump to calculate
8 values representing the performance of the fluid system;

9 using the system performance values to produce one or more command signals,
10 including the steps of selecting a fluid system performance parameter to control;
11 determining a setpoint for the selected fluid system performance parameter; calculating a
12 control signal using the setpoint value of the selected fluid system performance
13 parameter; and calculating the one or more command signals from the control signal; and
14 using the command signals to control the speed of the centrifugal pump,
15 wherein the selected fluid system performance parameter to control is the pump
16 suction pressure and wherein the step of using the one or more command signals to
17 control the speed of the centrifugal pump includes repetitively performing ~~the method~~
18 ~~comprising~~ the steps of:
19 operating the centrifugal pump at a set speed until the pump suction pressure
20 decreases to a value less than or equal to a pump suction pressure lower limit, said pump
21 suction pressure lower limit equal to the pump suction pressure setpoint minus a
22 tolerance;³ and
23 operating the centrifugal pump at zero speed until the pump suction pressure
24 increases to a value greater than or equal to a pump suction pressure upper limit, said
25 pump suction pressure upper limit equal to the pump suction pressure setpoint plus a
26 tolerance.

1 50. (Original) The method of claim 41 wherein the centrifugal pump is coupled to an
2 electric motor and the step of determining the torque and speed inputs to the centrifugal
3 pump comprises the steps of:

4 measuring values of electrical voltages applied to the motor and currents drawn by
5 the motor; and

6 using the measured values of electrical voltages applied to the motor and currents
7 drawn by the motor to calculate values for at least one of the parameters selected from the
8 group consisting of motor torque and motor speed.

1 51. (Currently Amended) The method of claim 50, wherein the step of using fluid system
2 performance values to produce one or more command signals comprises the further steps
3 of:

4 selecting a fluid system performance parameter to control;
5 ~~determining a~~ the setpoint value being derived for the selected fluid system
6 performance parameter;
7 calculating a control signal using the selected fluid system performance parameter;
8 and
9 calculating the one or more command signals from the control signal.

1 52. (Original) The method of claim 51, wherein the selected fluid system performance
2 parameter to control is the pump suction pressure.

1 53. (Currently Amended) ~~The method of claim 52,~~ A method of controlling the
2 performance of a fluid system wherein a centrifugal pump is used for transferring fluid
3 within said fluid system, wherein the centrifugal pump is coupled to an electric motor, the
4 method comprising the steps of:

5 determining values of torque and speed inputs to the centrifugal pump, including
6 the steps of measuring values of electrical voltages applied to the motor and currents
7 drawn by the motor, and using the measured values of electrical voltages applied to the
8 motor and currents drawn by the motor to calculate values for at least one of the
9 parameters selected from the group consisting of motor torque and motor speed;

10 using the values of torque and speed inputs to calculate one or more values
11 representing the performance of the centrifugal pump;

12 using the values representing the performance of the centrifugal pump to calculate
13 values representing the performance of the fluid system;

14 using the system performance values to produce one or more command signals,
15 including the steps of selecting a fluid system performance parameter to control,
16 including the steps of determining a setpoint for the selected fluid system performance
17 parameter, calculating a control signal using the selected fluid system performance
18 parameter, and calculating the one or more command signals from the control signal; and
19 using the one or more command signals to control the speed of the centrifugal
20 pump;
21 wherein the selected fluid system performance parameter to control is the pump
22 suction pressure, and further comprising the step of deriving the setpoint value for pump
23 suction pressure from a fluid level command.

1 54. (Original) The method of claim 53, further comprising the step of determining the
2 fluid level command, said step of determining the fluid level command comprising the
3 steps of:

4 defining a fluid system performance characteristic to optimize;
5 varying the fluid level incrementally through a range of values;
6 determining a value representing the fluid system performance characteristic for
7 each value of fluid level;
8 determining for which value of fluid level the value representing the fluid system
9 performance characteristic is optimized; and
10 setting the fluid level command at the level which produces the optimized value.

1 55. (Original) The method of claim 54, wherein the step of determining the fluid level
2 command is automatically repeated at predetermined times.

1 56. (Original) The method of claim 54, further comprising the step of periodically
2 determining the pump efficiency and repeating the step of determining the fluid level

3 command when a decrease in pump efficiency relative to prior determinations of pump
4 efficiency is detected.

1 57. (Original) The method of claim 54, wherein the system is a gas well, further
2 comprising the step of periodically determining the gas production and repeating the step
3 of determining the fluid level command when a decrease in gas production is detected.

1 58. (Currently Amended) ~~The method of claim 52;~~ A method of controlling the
2 performance of a fluid system wherein a centrifugal pump is used for transferring fluid
3 within said fluid system and wherein the centrifugal pump is coupled to an electric motor,
4 the method comprising the steps of:

5 determining values of torque and speed inputs to the centrifugal pump, including
6 the steps of measuring values of electrical voltages applied to the motor and currents
7 drawn by the motor, and using the measured values of electrical voltages applied to the
8 motor and currents drawn by the motor to calculate values for at least one of the
9 parameters selected from the group consisting of motor torque and motor speed;

10 using the values of torque and speed inputs to calculate one or more values
11 representing the performance of the centrifugal pump;

12 using the values representing the performance of the centrifugal pump to calculate
13 values representing the performance of the fluid system;

14 using the system performance values to produce one or more command signals,
15 including the steps of selecting a fluid system performance parameter to control,
16 including the steps of determining a setpoint for the selected fluid system performance
17 parameter, calculating a control signal using the selected fluid system performance
18 parameter, and calculating the one or more command signals from the control signal; and
19 using the one or more command signals to control the speed of the centrifugal
20 pump,

21 wherein the selected fluid system performance parameter to control is the pump
22 suction pressure, and wherein the step of using the one or more command signals to
23 control the speed of the centrifugal pump includes repetitively performing ~~the method~~
24 ~~comprising~~ the steps of:

25 operating the centrifugal pump at a set speed until the pump suction pressure
26 decreases to a value less than or equal to a pump suction pressure lower limit, said pump
27 suction pressure lower limit calculated as the pump suction pressure setpoint minus a
28 tolerance; and

29 operating the centrifugal pump at zero speed until the pump suction pressure
30 increases to a value greater than or equal to a pump suction pressure upper limit, said
31 pump suction pressure upper limit calculated as the pump suction pressure setpoint plus a
32 tolerance.

1 59. (Currently Amended) A method of controlling the performance of a fluid system
2 wherein a centrifugal pump is used for transferring fluid within said fluid system, the
3 method comprising the steps of:

4 determining a value of speed input to the centrifugal pump;

5 determining a value of pump flow rate;

6 using the value of speed input and the value of pump flow rate to calculate one or
7 more values representing the performance of the centrifugal pump;

8 using the values representing the performance of the centrifugal pump to calculate
9 values representing the performance of the fluid system;

10 using the system performance values to produce one or more command signals,

11 including deriving a setpoint value for a fluid system performance parameter from a fluid
12 level command, and using the setpoint value in calculating the one or more command
13 signals; and

14 using the one or more command signals to control the speed of the centrifugal
15 pump.

1 60. (Currently Amended) The method of claim 59, wherein the step of using fluid system
2 performance values to produce command signals comprises the further steps of:

3 selecting a fluid system performance parameter to control;

4 ~~determining a~~ the setpoint value being derived for the selected fluid system
5 performance parameter;

6 calculating a control signal using the setpoint value of the selected fluid system
7 performance parameter; and

8 calculating the one or more command signals from the control signal.

1 61. (Original) The method of claim 60, wherein the selected fluid system performance
2 parameter to control is the pump suction pressure.

1 62. (Currently Amended) ~~The method of claim 61,~~ A method of controlling the
2 performance of a fluid system, wherein a centrifugal pump is used for transferring fluid
3 within said fluid system, the method comprising the steps of:

4 determining a value of speed input to the centrifugal pump;

5 determining a value of pump flow rate;

6 using the value of speed input and the value of pump flow rate to calculate one or
7 more values representing the performance of the centrifugal pump;

8 using the values representing the performance of the centrifugal pump to calculate
9 values representing the performance of the fluid system;

10 using the system performance values to produce one or more command signals,

11 including the steps of selecting a fluid system performance parameter to control,

12 determining a setpoint for the selected fluid system performance parameter, calculating a

13 control signal using the setpoint value of the selected fluid system performance
14 parameter, and calculating the one or more command signals from the control signal; and
15 using the one or more command signals to control the speed of the centrifugal
16 pump,
17 wherein the selected fluid system performance parameter to control is the pump
18 suction pressure, and further comprising the step of deriving the setpoint value for pump
19 suction pressure from a fluid level command.

1 63. (Original) The method of claim 62, further comprising the step of determining the
2 fluid level command, said step of determining the fluid level command comprising the
3 steps of:
4 defining a fluid system performance characteristic to optimize;
5 varying the fluid level incrementally through a range of values;
6 determining a value representing the fluid system performance characteristic for
7 each value of fluid level;
8 determining for which value of fluid level the value representing the fluid system
9 performance characteristic is optimized; and
10 setting the fluid level command at the level which produces the optimized value.

1 64. (Original) The method of claim 63, wherein the step of determining the fluid level
2 command is automatically repeated at predetermined times.

1 65. (Original) The method of claim 63, further comprising the step of periodically
2 determining the pump efficiency and repeating the step of determining the fluid level
3 command when a decrease in pump efficiency relative to prior determinations of pump
4 efficiency is detected.

1 66. (Original) The method of claim 63, wherein the fluid system is a gas well, further
2 comprising the step of periodically determining the gas production and repeating the step
3 of determining the fluid level command when a decrease in gas production relative to
4 prior determinations of gas production is detected.

1 67. (Currently Amended) ~~The method of claim 61,~~ A method of controlling the
2 performance of a fluid system, wherein a centrifugal pump is used for transferring fluid
3 within said fluid system, the method comprising the steps of:
4 determining a value of speed input to the centrifugal pump;
5 determining a value of pump flow rate;
6 using the value of speed input and the value of pump flow rate to calculate one or
7 more values representing the performance of the centrifugal pump;
8 using the values representing the performance of the centrifugal pump to calculate
9 values representing the performance of the fluid system;
10 using the system performance values to produce one or more command signals,
11 including the steps of selecting a fluid system performance parameter to control,
12 determining a setpoint for the selected fluid system performance parameter, calculating a
13 control signal using the setpoint value of the selected fluid system performance
14 parameter, and calculating the one or more command signals from the control signal; and
15 using the command signals to control the speed of the centrifugal pump,
16 wherein the selected fluid system performance parameter to control is the pump
17 suction pressure; and wherein the step of using the command signals to control the speed
18 of the centrifugal pump includes repetitively performing the method comprising the steps
19 of:
20 operating the centrifugal pump at a set speed until the pump suction pressure
21 decreases to a value less than or equal to a pump suction pressure lower limit, said pump

22 suction pressure lower limit calculated as the pump suction pressure setpoint minus a
23 tolerance; and
24 operating the centrifugal pump at zero speed until the pump suction pressure
25 increases to a value greater than or equal to a pump suction pressure upper limit, said
26 pump suction pressure upper limit calculated as the pump suction pressure setpoint plus a
27 tolerance.

1 68. (Original) The method of claim 59 wherein the centrifugal pump is coupled to an
2 electric motor and the step of determining the speed input to the centrifugal pump
3 comprises the steps of:

4 measuring values of electrical voltages applied to the motor and currents drawn by
5 the motor; and

6 using the measured values of electrical voltages applied to the motor and currents
7 drawn by the motor to calculate a value for motor speed.

1 69. (Currently Amended) The method of claim 68, wherein the step of using fluid system
2 performance values to produce command signals comprises the steps of:

3 selecting a fluid system performance parameter to control;

4 ~~determining a~~ the setpoint being derived for the selected fluid system performance
5 parameter;

6 calculating a control signal using the selected fluid system performance parameter;
7 and

8 calculating the one or more command signals from the control signal.

1 70. (Original) The method of claim 69, wherein the selected fluid system performance
2 parameter to control is the pump suction pressure.

1 71. (Currently Amended) ~~The method of claim 70,~~ A method of controlling the
2 performance of a fluid system wherein a centrifugal pump is used for transferring fluid
3 within said fluid system, and wherein the centrifugal pump is coupled to an electric
4 motor, the method comprising the steps of:
5 determining a value of speed input to the centrifugal pump, including the steps of
6 measuring values of electrical voltages applied to the motor and currents drawn by the
7 motor, and using the measured values of electrical voltages applied to the motor and
8 currents drawn by the motor to calculate a value for motor speed
9 determining a value of pump flow rate;
10 using the value of speed input and the value of pump flow rate to calculate one or
11 more values representing the performance of the centrifugal pump;
12 using the values representing the performance of the centrifugal pump to calculate
13 values representing the performance of the fluid system, including the steps of selecting a
14 fluid system performance parameter to control, determining a setpoint for the selected
15 fluid system performance parameter, calculating a control signal using the selected fluid
16 system performance parameter, and calculating one or more command signals from the
17 control signal;
18 using the system performance values to produce the one or more command
19 signals; and
20 using the command signals to control the speed of the centrifugal pump,
21 wherein the selected fluid system performance parameter to control is the pump
22 suction pressure, and further comprising the step of deriving the setpoint value for pump
23 suction pressure from a fluid level command.

1 72. (Original) The method of claim 71, further comprising the step of determining the
2 fluid level command, said step of determining the fluid level command comprising the
3 steps of:

4 defining a fluid system performance characteristic to optimize;

5 varying the fluid level incrementally through a range of values;

6 determining a value representing the fluid system performance characteristic for
7 each value of fluid level;

8 determining for which value of fluid level the value representing the fluid system
9 performance characteristic is optimized; and

10 setting the fluid level command at the level which produces the optimized value.

1 73. (Original) The method of claim 72, wherein the step of determining the fluid level
2 command is automatically repeated at predetermined times.

1 74. (Original) The method of claim 72, further comprising the step of periodically
2 determining the pump efficiency and repeating the step of determining the fluid level
3 command when a decrease in pump efficiency relative to prior determinations of pump
4 efficiency is detected.

1 75. (Original) The method of claim 72, wherein the system is a gas well, further
2 comprising the step of periodically determining the gas production and repeating the step
3 of determining the fluid level command when a decrease in gas production is detected.

1 76. (Currently Amended) ~~The method of claim 70,~~ A method of controlling the
2 performance of a fluid system wherein a centrifugal pump is used for transferring fluid
3 within said fluid system, and wherein the centrifugal pump is coupled to an electric
4 motor, the method comprising the steps of:

5 determining a value of speed input to the centrifugal pump, including the steps of
6 measuring values of electrical voltages applied to the motor and currents drawn by the
7 motor, and using the measured values of electrical voltages applied to the motor and
8 currents drawn by the motor to calculate a value for motor speed;

9 determining a value of pump flow rate;

10 using the value of speed input and the value of pump flow rate to calculate one or
11 more values representing the performance of the centrifugal pump;

12 using the values representing the performance of the centrifugal pump to calculate
13 values representing the performance of the fluid system, including the steps of using the
14 system performance values to produce one or more command signals; selecting a fluid
15 system performance parameter to control, determining a setpoint for the selected fluid
16 system performance parameter; calculating a control signal using the selected fluid
17 system performance parameter; and calculating the one or more command signals from
18 the control signal; and

19 using the one or more command signals to control the speed of the centrifugal
20 pump,

21 wherein the selected fluid system performance parameter to control is the pump
22 suction pressure, and wherein the step of using the one or more command signals to
23 control the speed of the centrifugal pump includes repetitively performing the method
24 comprising the steps of:

25 operating the centrifugal pump at a set speed until the pump suction pressure
26 decreases to a value less than or equal to a pump suction pressure lower limit, said pump
27 suction pressure lower limit calculated as the pump suction pressure setpoint minus a
28 tolerance; and

29 operating the centrifugal pump at zero speed until the pump suction pressure
30 increases to a value greater than or equal to a pump suction pressure upper limit, said

31 pump suction pressure upper limit calculated as the pump suction pressure setpoint plus a
32 tolerance.

1 77. (Original) A method of controlling the performance of a fluid system wherein at least
2 first and second centrifugal pumps are connected in parallel and are used for transferring
3 fluid within said fluid system, the method comprising the steps of:
4 determining values of speed input to each of the centrifugal pumps;
5 determining values pump flow rate of each of the centrifugal pumps;
6 using the values of speed input and pump flow rate to calculate the efficiency of
7 each centrifugal pump;
8 using efficiency and flow of each centrifugal pump to calculate the speed for each
9 centrifugal pump which would result in the most efficient operation of the fluid system;
10 using the calculated speed for each centrifugal pump to produce command signals;
11 and
12 using the command signals to control the speed of each centrifugal pump.

1 78. (Original) The method of claim 77 wherein the first and second centrifugal pumps are
2 coupled to first and second electric motors, respectively, and the step of determining the
3 speed input to each of the centrifugal pumps coupled to an electric motor comprises the
4 steps of:
5 measuring values of electrical voltages applied to the first and second motors and
6 currents drawn by the first and second motors; and
7 using the measured values of electrical voltages applied to the first and second
8 motors and currents drawn by the first and second motors to calculate for the first and
9 second centrifugal pumps values for at least one of the parameters selected from the
10 group consisting of motor torque and motor speed.

1 79. (Original) The method of claim 77, wherein the step of determining the pump flow
2 rate of each of the centrifugal pumps comprises the steps of:

3 determining values of torque input to each of the centrifugal pumps; and
4 using the values of torque inputs and speed inputs to the first and second motors
5 and currents drawn by the first and second motors to calculate for the first and second
6 centrifugal pumps values for pump flow rate.

1 80. (Original) A method of controlling the performance of a fluid system wherein a
2 centrifugal pump is used for transferring fluid within said fluid system, the method
3 comprising the steps of:

4 selecting a fluid system performance parameter to control;
5 determining a setpoint for the selected fluid system performance parameter;
6 determining values representing the performance of the centrifugal pump;
7 determining values representing the performance of the fluid system;
8 using the pump performance values and fluid system performance values to
9 calculate a feedforward signal by predicting a value of mechanical input to the centrifugal
10 pump when operating with the selected centrifugal pump performance value at the
11 setpoint value;
12 using the feedforward signal to generate command signals; and
13 using the command signals to control the speed of the centrifugal pump.

1 81. (Original) The method of claim 80, wherein the selected fluid system performance
2 parameter to control is the pump suction pressure.

1 82. (Original) The method of claim 81, further comprising the step of deriving the
2 setpoint value for pump suction pressure from a fluid level command.

1 83. (Original) The method of claim 82, further comprising the step of determining the
2 fluid level command, said step of determining the fluid level command comprising the
3 steps of:

4 defining a fluid system performance characteristic to optimize;

5 varying the fluid level incrementally through a range of values;

6 determining a value representing the fluid system performance characteristic for
7 each value of fluid level;

8 determining for which value of fluid level the value representing the fluid system
9 performance characteristic is optimized; and

10 setting the fluid level command at the level which produces the optimized value.

1 84. (Original) The method of claim 83, wherein the step of determining the fluid level
2 command is automatically repeated at predetermined times.

1 85. (Original) The method of claim 83, further comprising the step of periodically
2 determining the pump efficiency and repeating the step of determining the fluid level
3 command when a decrease in pump efficiency relative to prior determinations of pump
4 efficiency is detected.

1 86. (Original) The method of claim 83, wherein the system is a gas well, further
2 comprising the step of periodically determining the gas production and repeating the step
3 of determining the fluid level command when a decrease in gas production is detected.

1 87. (Original) The method of claim 81, wherein the step of using the command signals to
2 control the speed of the centrifugal pump includes repetitively performing the method
3 comprising the steps of:

4 operating the centrifugal pump at a set speed until the pump suction pressure
5 decreases to a value less than or equal to a pump suction pressure lower limit, said pump

suction pressure lower limit calculated as the pump suction pressure setpoint minus a tolerance; and

operating the centrifugal pump at zero speed until the pump suction pressure increases to a value greater than or equal to a pump suction pressure upper limit, said pump suction pressure upper limit calculated as the pump suction pressure setpoint plus a tolerance.

88. (Cancelled)

89. (Cancelled).

90. (Currently Amended) ~~The pump control system of claim 89,~~ A pump control system for controlling a centrifugal pump for transferring fluid within a wellbore, the pump control system comprising:

a plurality of sensors;

means responsive to the sensors for determining values of torque and speed input to the centrifugal pump;

means for using the values of torque and speed input to calculate one or more values representing the performance of the centrifugal pump; and

means for using the centrifugal pump performance values to produce one or more command signals for controlling the speed of the centrifugal pump, wherein none of the sensors are located within the wellbore, whereby the values of torque and speed input are derived using sensed values without requiring down hole sensors,

wherein said means using the centrifugal pump performance values to produce command signals includes means for calculating a feedback signal indicative of the difference between a current value of a selected centrifugal pump performance parameter and a setpoint value of the selected centrifugal pump performance parameter; and means for calculating the command signals from the feedback signal.

1 91. (Original) The pump control system of claim 90, wherein the selected centrifugal
2 pump performance parameter is the pump flow rate.

1 92. (Original) The pump control system of claim 90, wherein the selected centrifugal
2 pump performance parameter is the pump head pressure.

1 93. (Currently Amended) ~~The pump control system of claim 89, The pump control~~
2 ~~system of claim 89, A pump control system for controlling a centrifugal pump for~~
3 transferring fluid within a wellbore, the pump control system comprising:
4 a plurality of sensors;
5 means responsive to the sensors for determining values of torque and speed input
6 to the centrifugal pump;
7 means for using the values of torque and speed input to calculate one or more
8 values representing the performance of the centrifugal pump; and
9 means for using the centrifugal pump performance values to produce one or more
10 command signals for controlling the speed of the centrifugal pump, wherein none of the
11 sensors are located within the wellbore, whereby the values of torque and speed input are
12 derived using sensed values without requiring down hole sensors,
13 wherein said means using the centrifugal pump performance values to produce
14 command signals includes means for calculating a feedforward signal by predicting a
15 value of mechanical input to the centrifugal pump when operating with the selected
16 centrifugal pump performance value at the setpoint value, and means for calculating the
17 command signals from the feedforward signal.

18 94. (Original) The pump control system of claim 91, including means for repetitively
19 switching the speed of the centrifugal pump between a set pump speed for a portion of a
20 cycle period and zero speed for the remainder of the cycle period to achieve an average
21 pump flow rate equal to the setpoint value of the pump flow rate.

1 95. (Original) A pump control system for controlling a centrifugal pump for transferring
2 fluid within a fluid system, the pump control system comprising:

3 means for determining a value of speed input to the centrifugal pump;

4 means for determining a value of pump flow rate of the centrifugal pump;

5 means for using the values of pump flow rate and speed input to calculate one or
6 more values representing the performance of the centrifugal pump; and

7 means for using the centrifugal pump performance values to produce one or more
8 command signals for controlling the speed of the centrifugal pump;

9 means for calculating a feedforward signal by predicting a value of mechanical
10 input to the centrifugal pump when operating with the selected centrifugal pump
11 performance value at the setpoint value, and means for calculating the command signals
12 from the feedforward signal.

1 96. (Original) The pump control system of claim 95, wherein said means for using the
2 centrifugal pump performance values to produce command signals includes means for
3 calculating a feedback signal indicative of the difference between a current value of a
4 selected centrifugal pump performance parameter and a setpoint value of the selected
5 centrifugal pump performance parameter, and means for calculating the command signals
6 from the feedback signal.

1 97. (Original) The pump control system of claim 96, wherein the selected centrifugal
2 pump performance parameter is the pump head pressure.

1 98. (Original) The pump control system of claim 95, wherein said means for using the
2 centrifugal pump performance values to produce command signals includes means for
3 calculating a feedforward signal by predicting a value of mechanical input to the
4 centrifugal pump when operating with the selected centrifugal pump performance value

5 at the setpoint value, and means for calculating the command signals from the
6 feedforward signal.

1 99. (Original) The pump control system of claim 96, wherein the selected centrifugal
2 pump performance parameter is the pump flow rate, including means for repetitively
3 switching the speed of the centrifugal pump between a set pump speed for a portion of a
4 cycle period and zero speed for the remainder of the cycle period to achieve an average
5 pump flow rate equal to the setpoint value of the pump flow rate.

1 100. (Currently Amended) A pump control system for controlling a centrifugal pump for
2 transferring fluid within a gas or oil well, the pump control system comprising:

3 means to calculate one or more values representing the performance of the
4 centrifugal pump;

5 means for using the values representing the performance of the centrifugal pump
6 to calculate values representing the performance of the well;

7 means for using at least one of the system performance ~~values to calculate~~values to
8 calculate a feedforward signal; and

9 means responsive to at least one of the system performance values and to the
10 feedforward signal to produce one or more command signals for controlling the speed of
11 the centrifugal pump.

1 101. (Original) The pump control system of claim 100, wherein said means for using the
2 performance values to produce command signals includes means for calculating a
3 feedback signal indicative of the difference between a current value of the selected
4 performance parameter and a setpoint value of the selected performance parameter; and
5 means for using the feedback signal to calculate the command signals.

1 102. (Original) The pump control system of claim 100, wherein said means for
2 calculating the feedforward signal includes means for predicting a value of mechanical
3 input to the centrifugal pump when operating with the selected pump performance value
4 at the setpoint value.

1 103. (Original) The pump control system of claim 101, wherein the selected performance
2 parameter is the pump suction pressure.

1 104. (Original) The pump control system of claim 103, wherein said means for using the
2 performance values to produce command signals includes means for calculating the
3 setpoint for pump suction pressure from a fluid level command.

1 105. (Original) The pump control system of claim 104, wherein said means for using the
2 system performance values to produce command signals includes means for periodically
3 determining gas or oil production and adjusting fluid level command in response to
4 detection of a decrease in gas or oil production.

1 106. (Original) The pump control system of claim 103, wherein said means for using the
2 command signals to control the speed of the centrifugal pump includes means for
3 operating the centrifugal pump at a set speed until the pump suction pressure decreases to
4 a value less than or equal to a pump suction pressure lower limit that is equal to the pump
5 suction pressure setpoint minus a tolerance; and means for operating the centrifugal pump
6 at zero speed until the pump suction pressure increases to a value greater than or equal to
7 a pump suction pressure upper limit that is equal to the pump suction pressure setpoint
8 plus a tolerance.

107. (Cancelled).

1 108. (Currently Amended) ~~The pump control system of claim 107~~ A pump control system
2 for controlling at least first and second centrifugal pumps connected in parallel for
3 transferring fluid within a fluid system, the pump control system comprising:

4 means to determine values for the efficiency and flow of each centrifugal pump;

5 means for using the values of efficiency and flow of each centrifugal pump to
6 calculate a speed for each centrifugal pump which would result in the most efficient
7 operation of the fluid system;

8 means for using the calculated speed for each centrifugal pump to produce
9 command signals; and

10 means for using the command signals to control the speed of each centrifugal
11 pump.

12 wherein at least one centrifugal pump is coupled to an electric motor and the
13 means for determining the efficiency and flow rate of at least one centrifugal pump
14 coupled to an electric motor includes means for measuring the electrical voltages applied
15 to the motor and currents drawn by the motor; and

16 means for using the measured values of electrical voltages applied to the motor
17 and currents drawn by the motor to calculate at least one of the values selected from the
18 group consisting of motor torque and motor speed.

1 109. (Original) A pump control system for controlling a centrifugal pump for transferring
2 fluid within a fluid system, the pump control system comprising:

3 means for determining values representing the performance of the centrifugal
4 pump;

5 means for determining values representing the performance of the fluid system;

6 means for calculating a feedforward signal by predicting a value of mechanical
7 input to the centrifugal pump when operating with a selected centrifugal pump
8 performance value at a setpoint value; and
9 means for calculating from the feedforward signal one or more command signals
10 for controlling the speed of the centrifugal pump.

1 110. (Original) The pump control system of claim 109, wherein the selected performance
2 parameter is the pump suction pressure.

1 111. (Original) The pump control system of claim 110, wherein said means for
2 calculating a feedforward signal includes means for calculating the setpoint for pump
3 suction pressure from a fluid level command.

1 112. (Original) The pump control system of claim 111, wherein said means for
2 calculating a feedforward signal includes means for periodically determining gas or oil
3 production and adjusting fluid level command in response to detection of a decrease in
4 gas or oil production.

1 113. (Original) The pump control system of claim 110, wherein said means for using the
2 command signals to control the speed of the centrifugal pump includes means for
3 operating the centrifugal pump at a set speed until the pump suction pressure decreases to
4 a value less than or equal to a pump suction pressure lower limit that is equal to the pump
5 suction pressure setpoint minus a tolerance; and means for operating the centrifugal pump
6 at zero speed until the pump suction pressure increases to a value greater than or equal to
7 a pump suction pressure upper limit that is equal to the pump suction pressure setpoint
8 plus a tolerance.

1 114. (Original) A pump control system for controlling a centrifugal pump for transferring
2 fluid within a gas or oil well, the pump control system comprising:

means for determining values representing the performance of the centrifugal pump;

means for determining values representing the performance of the well;

means for calculating a feedforward signal by predicting a value of mechanical input to the centrifugal pump when operating with a selected centrifugal pump performance value at a setpoint value; and

means for calculating from the feedforward signal one or more command signals for controlling the speed of the centrifugal pump.

115. (Original) The pump control system of claim 114, wherein the selected performance parameter is the pump suction pressure.

116. (Original) The pump control system of claim 115, wherein said means for calculating a feedforward signal includes means for calculating the setpoint for pump suction pressure from a fluid level command.

117. (Original) The pump control system of claim 116, wherein said means for calculating a feedforward signal includes means for periodically determining gas or oil production and adjusting fluid level command in response to detection of a decrease in gas or oil production.

118. (Original) The pump control system of claim 115, wherein said means for using the command signals to control the speed of the centrifugal pump includes means for operating the centrifugal pump at a set speed until the pump suction pressure decreases to a value less than or equal to a pump suction pressure lower limit that is equal to the pump suction pressure setpoint minus a tolerance; and means for operating the centrifugal pump at zero speed until the pump suction pressure increases to a value greater than or equal to

- 7 a pump suction pressure upper limit that is equal to the pump suction pressure setpoint
- 8 plus a tolerance.